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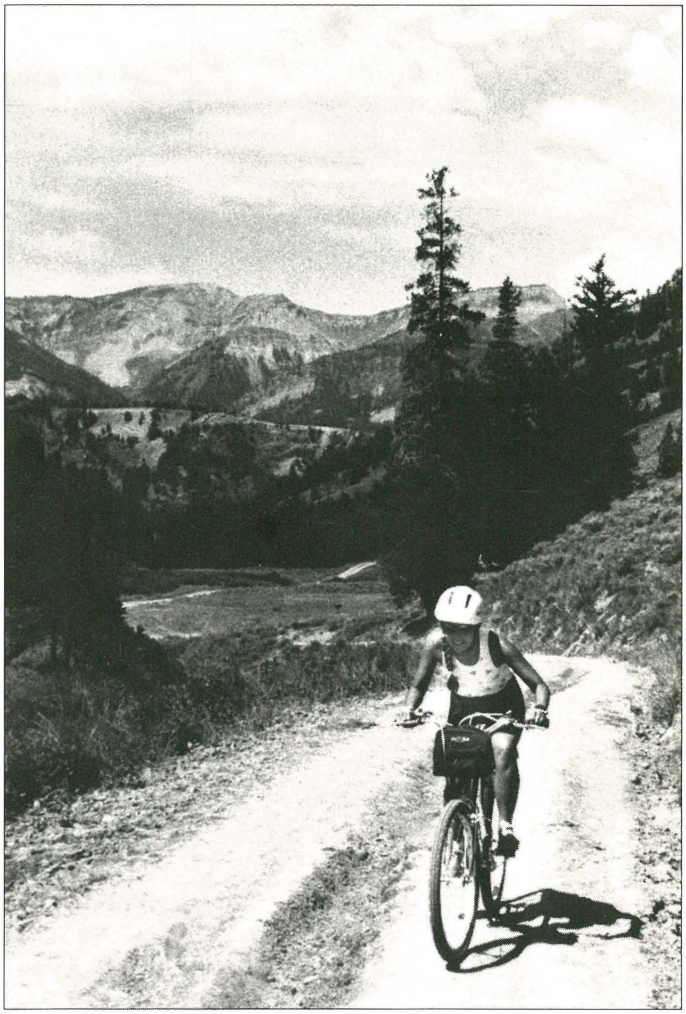
Mountain Bike Trails:

Techniques for Design, Construction and Maintenance



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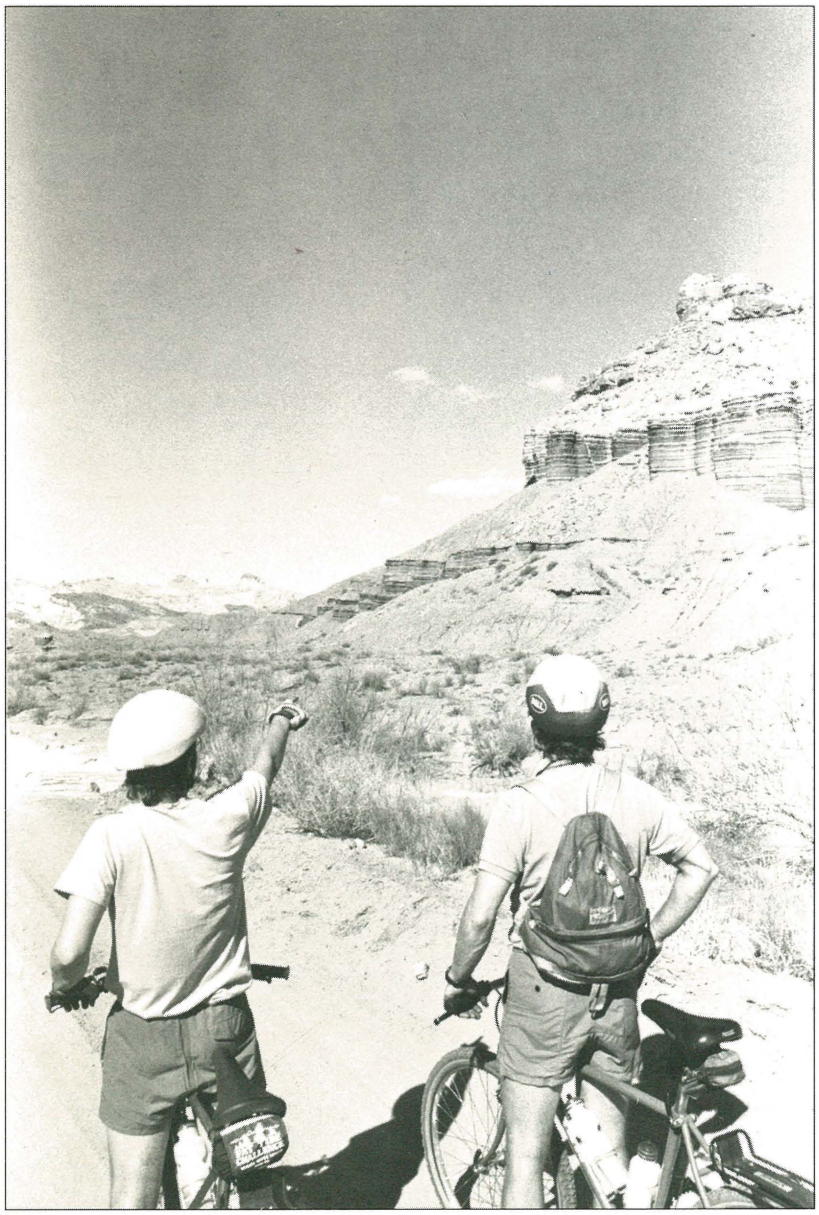
Introduction

Mountain biking is an increasingly popular form of outdoor recreation. Mountain bike enthusiasts are a diverse group with a variety of expectations. Some bicyclists view mountain biking as a new and different way to enjoy the outdoors, and others enjoy riding challenging trails. Developing ways to integrate the thousands of mountain bike enthusiasts into the existing trails system on public lands is a challenge for recreation managers. In 1991, the USDA Forest Service's Missoula Technology and Development Center, and Bikecentennial, a 30,000-member not for profit recreational bicycling organization, agreed to cooperate to consolidate mountain bike trail information into a guide for recreation managers. This guide is intended to assist managers in their efforts to design, adapt and maintain trails for mountain bike use. It will be most useful to those individuals with direct knowledge of trail construction and maintenance techniques. It is meant to



complement, not replace, standard agency specifications for trail construction such as the Forest Service Handbook 2309.18 Trails Management Handbook, and Forest Service Standard Specifications for Construction of Trails EM-7720-102 and National Park Service Trails Management Handbook NPS-2023.

Each time that a new use is introduced to the trail system the resource is affected in a unique way. Other user groups have created unique impacts in the past and now bicycle impacts are being noted. Managers can minimize conflict, reduce resource impacts and maximize user satisfaction by engineering and constructing trails carefully, maintaining trails regularly, and cooperating with users. ■

Acknowledgments

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Techniques for Design, Construction and Maintenance

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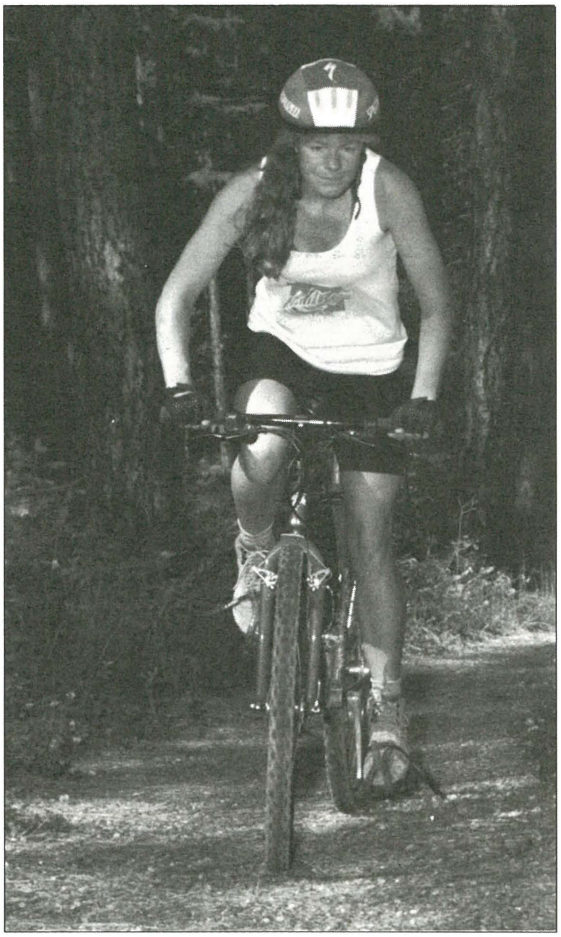

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Trail Planning and Layout

Trail planning and layout should be based on standard agency trail planning guidelines. This section is intended to supplement that information.

Mountain-bike trail design begins with careful analysis of existing trails and roads. As stated in the Forest Service Trails Management Handbook (FSH 2309.18 TMH section 2.31c), mountain bikes can be ridden on trails designed for hikers, equestrians, motorized bikes, cross-country skiers, and four-wheel drive vehicles. Trail designers can sometimes incorporate existing skid trails and roads from timber sales in bicycle routes. In some cases, abandoned railroad grades can offer excellent opportunities as mountain bicycle trails. Be sure to involve local bicycle enthusiasts in the planning process, for they often will know of existing and potential trail opportunities.

Opportunities and Constraints

Identify existing trails and primitive roads that are suitable for mountain bike use. Note the type and volume of traffic on these existing roads and trails. Identify locations with road or trail erosion, areas with inadequate drainage, and other situations where maintenance may be difficult and rerouting may be necessary. Look for natural barriers to control water and erosion, such as rock walls or steep banks. A mountain bike trail data sheet can be used to catalog this and any additional information. (See Appendix A.) Managers who are able to utilize existing trails and roads often need only construct short connector trails instead of constructing entirely new trail systems.

Identify interest and avoidance areas on a topographic map before constructing new or adapting existing trails for mountain bike use. Interest areas include features that a trail should encounter, such as waterfalls, unusual plants, unusually large and old trees (Photo 1), unique vista points, and convenient stream-crossing locations. Avoidance areas include features that the trail should not intersect or traverse, such as soils that erode easily, wet or swampy areas, high-elevation north slopes that hold snow long into spring, dangerous cliffs, and sensitive cultural resource sites and plant and animal habitat.

Identifying stream crossings is an important part of mountain bike trail planning. Ideally, the approach to a stream crossing should be flat and visible from at least 50 feet away. Mountain bikers can ride through surprisingly deep and/or wide running streams and, in fact, many eagerly anticipate doing so (Photo 2). If the stream bed and banks will not be adversely affected by bicycle use, managers may want to provide a ford instead of a bridge. A good ford has low banks that do not drop off steeply and a stream bed that consists of cobbles or gravel rather than silt.

Opportunities and constraints can be recorded on an overlay system. An overlay system used in Colorado by the Jefferson County Open Space

PONDEROSA PINE
(Pinus ponderosa)
THIS FOREST GIANT IS THE LARGEST KNOWN TREE OF ITS KIND STANDING ANYWHERE IN MONTANA IT IS ALSO THE MONTANA STATE TREE. IT MEASURES 78 INCHES IN DIAMETER AT BREAST HEIGHT AND IS 194 FEET TALL. IT CONTAINS 17,107 BOARD FEET OF LUMBER. ENOUGH TO BUILD TWO AVERAGE SIZE HOUSES. THIS TREE IS 335 YEARS OLD AND IS STILL GROWING.

Photo 1. This ponderosa pine tree is an excellent example of a feature that a trail might pass by.

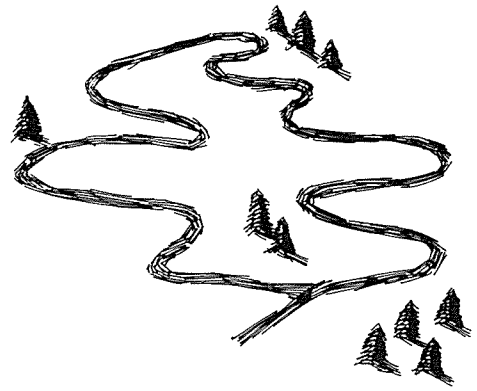
Photo 2. The gradual approach and cobble bed of this stream allow cyclists to ride through it confidently.

Division in their Preliminary Trails Plan for the Evergreen Mountain Bicycle Park presents an excellent way to record information. They used three overlays: a *base conditions overlay* identified water features, plant zones, and vegetative cover; a *constraints overlay* identified slope, problem soils, and sensitive environments; and an *opportunities overlay* identified roads, trails, viewpoints, and slope aspect.

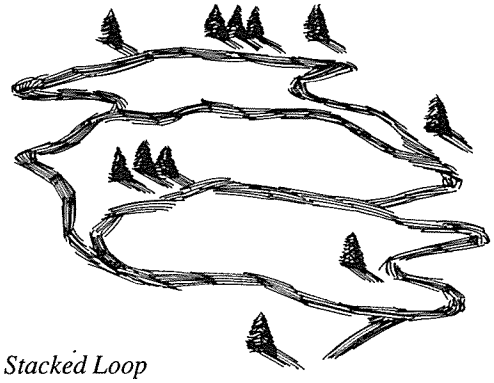
Layout Patterns

Ideally, mountain bike trail systems should form multiple loops. Loop trails are desirable because they do not require bicyclists to pass over the same terrain more than once. The most successful trails appear to be *stacked loop* and *maze* trails that have 10 to 100 miles of interconnecting loops. These trails allow bicyclists to design their own ride and choose the distance they want to travel (Illustration 1). When planning stacked loop trails, loops should progress from the easiest routes to the most difficult. Be careful not to over-trail an area with numerous short loops. In general, bicyclists enjoy longer, open loops with occasional options for shorter loops. Many people enjoy loop trails because they can begin and end their ride in the same location. However, managers should not rule out the development of a trail because it does not loop. Many cyclists won't mind shuttling cars or travelling out and back on the same trail in order to experience an interesting ride.

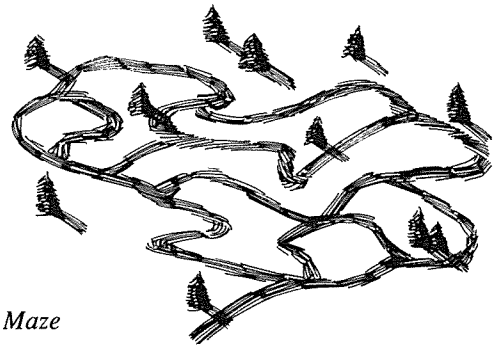
Illustration 1. Examples of loop trail designs.



a. Simple Loop



b. Stacked Loop



c. Maze

Directing, Dispersing, and Separating Users

Where use becomes too concentrated managers can disperse users by marketing other existing opportunities or providing additional opportunities. This increases user satisfaction while reducing the potential for conflict among user groups. Dispersing users also reduces the potential for environmental damage from heavy use. Managers from the San Juan National Forest and the Montrose District of the Bureau of Land Management have developed a mountain bicycle trail guide called "Bicycle Routes on Public Lands of Southwest Colorado," which describes 37 different routes for all skill levels. It has been particularly effective in dispersing use.

One key element in reducing user conflict is ensuring that users know what to expect and what other trail users they might encounter. If resource impacts or user conflicts occur along loop routes that use a combination of unpaved roads and trails, managers may want to encourage one-way travel. When bicyclists ride uphill, they travel much more slowly and take more time to rest and look around. Often, trails are more aesthetically pleasing than roads. In that situation, if the route is set up so that the trail is the uphill portion and the road is the downhill portion, the majority of the bicyclist's time is spent in the more pleasing setting. Bicyclists travel faster on downhill sections, and roads are typically wider and provide greater visibility. This can help reduce user conflicts by allowing users time to react to oncoming traffic.

However, many bicyclists enjoy choosing their direction of travel and riding down narrow trails. These bicyclists may feel restricted by "up trail and down road" designations. Providing information that explains the reasons for these designations may increase cooperation.

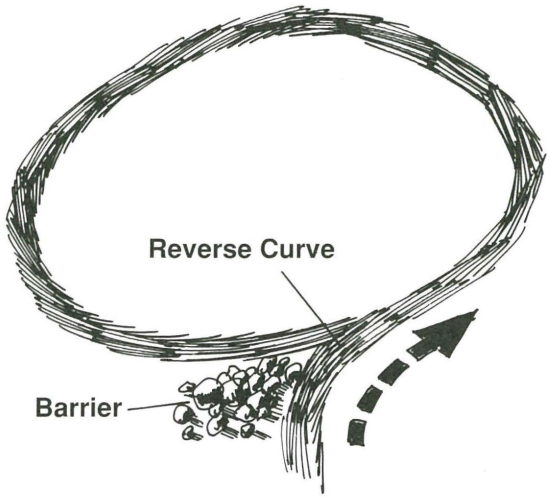


Illustration 2. Reverse curve trail design encourages one-way traffic to the right.

There may be situations where one-way trail use is desirable. Some users may resent the limitation of one-way directional signing. Such signing may create conflicts with users since they will not be prepared for people who violate the one-way designation. (3) A more subtle method for directing traffic flow is to design loop trails so that the entrance trail angles gently to the right and the exit trail ties back in on the left at greater than a 90 degree angle (Illustration 2). With this design, the majority of people will circle the loop to the right. (4) This design encourages, rather than demands, a specific traffic flow and since there are no directional signs, users will not expect one-way traffic.

Some public land agencies have attempted to prevent user conflicts and lessen resource impacts by separating user groups. However, experience has shown that people often respond negatively to being excluded, compliance can be difficult to enforce, and providing separate trails may be expensive. Separating user groups also limits opportunities for communication and cooperation among users. There may, however, be times when separation is necessary. If this is the case, encourage rather than designate separate use and post this explanatory information at trailheads or in trail guides. Separation may be an effective tactic at trailheads. In some locations, up to 80 percent of trail traffic is concentrated in the first half-mile from the trailhead. (5) Separate trailhead facilities or separate entrance trails from the trailhead may be an effective technique to help reduce user conflicts and overuse near the beginning of the trail.

To avoid creating new or aggravating current tensions between user groups, mountain bicycle races should not be permitted on sensitive trails or those heavily traveled by other user groups.

Trail Alignment

When planning new or adapting existing trails, managers should strive to create interesting routes that provide for user satisfaction and resource protection. Mountain bikers enjoy trails that wind around when traversing flat sections, and dip up and down, playing with the terrain, as they cross low ridges and drainages. The trails should incorporate broad sweeping curves and short up- and downhill sections (Photo 3). Occasional short grades at or near the maximum degree of difficulty enhance the rider's experience. Steep pitches should not parallel the fall line, but instead should traverse across it. The steepest inclines should occur only in soils that are relatively resistant to erosion.

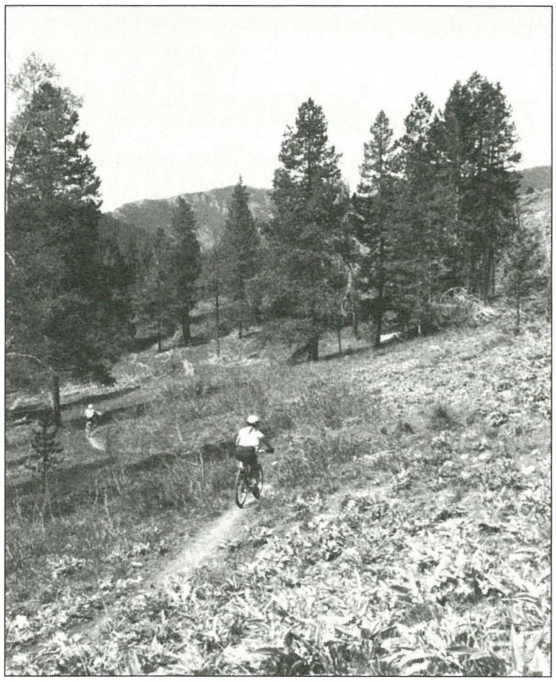


Photo 3. Narrow tread and frequent dips and bends make this trail interesting to mountain bike riders.

Some bicyclists enjoy long, steep climbs, others like the challenge of single-track trails, and others are partial to less challenging terrain. Many enjoy all three at different times. Offering a variety of experiences will help managers provide for user satisfaction and resource protection.

Managers on the Los Padres National Forest in California have built trails with rolls that rise 2 feet and then dip 1 foot along a 20-40 foot section of trail. This rolling technique traps and moves water off the trail, slows the bicyclist's speed, and enhances the rider's experience. The roll and dip technique works best on trails with a grade of 2 percent or greater because water has a tendency to collect in dips along level trails. (1) If terrain is too flat for rolls and dips, turns can be constructed to increase user satisfaction and encourage bicyclists to ride more slowly.

Visibility (Sight Distances)

The ideal mountain-bike trail includes turns and bends at regular intervals. Since constant turns and bends reduce sight distance, most bicyclists will travel more slowly and apply the brakes consistently and more gently under these conditions. Sudden, tight turns preceded by long straight sections of trail may cause bicyclists to lock their brakes. This can cause resource impacts as well as danger to other trail users. Where possible, provide broad sweeping turns on downhill sections.

Managers in wildland/urban interface areas suggest that short sight distances can cause conflicts on heavily used trails, and longer sight distances allow trail users to be better prepared for encounters.

Trail Grade

Grade is the slope maintained by the trail in its direction of travel. When possible, avoid long, steep downhill grades on mountain bike trails. When bicyclists travel down steep grades they may lock their brakes and skid. Rocks and soil may be displaced and resource impacts can occur. Safety and user conflicts are more common on downhill stretches of trail where bicyclists are likely to increase their speed. On steep, uphill grades of 15 percent or greater, most riders will dismount and push their bicycles. So, if a mountain-bike trail must include steep grades and the trail can sustain the use, incorporate steep grades as uphill sections rather than as downhill sections.

Widen trails where bicyclists are most apt to dismount and walk. If a widened trail is not provided, bicyclists may be forced to push their bicycles along the edge of the trail.

The approach grade to intersections should be kept to under 5 percent to minimize user conflicts and resource impacts caused by sudden braking or skidding.

Bicycle wheels may form ruts in wet or poorly drained soils. On steep slopes these ruts channel water down-slope. As the amount of water channeled down the grade increases, the ruts grow larger and carry off more soil. Managers can minimize rutting by locating trails across the slope rather than straight up and down the fall line, and by installing water control structures.

When determining the upper limit of the grade, consider the nature of the trail surface and the relative degree of traction it provides. This includes soil types, vegetation types, and the amount of rock present.

Trail Surface

Traditionally, managers have cleared trails of barriers to create smooth surfaces. Clear, smooth trails, however, allow bicyclists to confidently increase their speed and, in some instances, this can be a problem. Leaving slightly rougher, natural surfaces may encourage bicyclists to ride more slowly. (2) Protruding rocks, roots, bumps, downed trees, and gravel can work to slow bicyclists and other users in appropriate settings

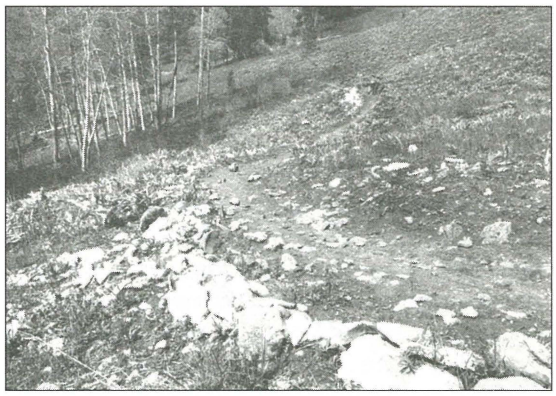


Photo 4. The rough surface on this trail helps to slow bicyclists as they travel down the trail.

(Photo 4). It is important to provide rough surfaces on some trails for those seeking challenging trail experiences, and smooth trails for those seeking less challenge. Information about the hazards associated with mountain bike trail riding can be provided at trailheads and in trail guides.

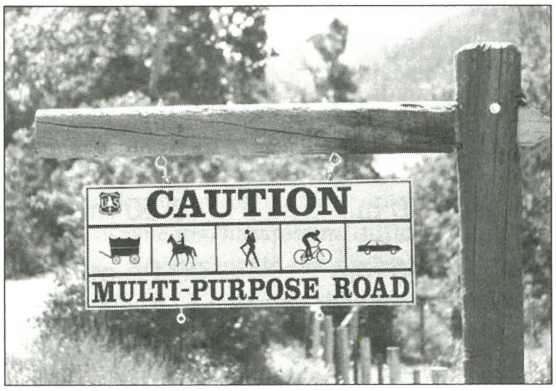
Some managers of wildland/urban interface trails caution against leaving the surface rough where trail traffic is heavy, for under such conditions it can be more difficult for bicyclists to stop quickly.

Managers should work with local soil scientists to identify erosion-prone and impact-resistant soils before locating or adapting trails and determining trail difficulty levels. Changes in weather can cause changes in the trail's surface and difficulty level. A clay trail that resists erosion and is easy to ride when dry can become erosive and difficult to ride when wet and soft. Be sure to consider such variation when designing trails for mountain bike use.

Signing

Sign specialists should be involved when managers plan signing needs for trails. There are specific rules and regulations regarding size, color, message and other information on signs. Over-signing has been a problem in some areas. This section presents a variety of locations and types of signs that managers should consider before carefully determining the signing needs.

Signs should be posted at appropriate trailheads. Signing might include information about the modes of accepted travel, trail difficulty and trail length. In addition, signs may include trail maps, hazard warnings (which should meet Manual on Uniform Traffic Control Devices [MUTCD] standards),



emergency help phone numbers or locations, "tread lightly" messages, control signs such as speed limits, and trail etiquette guidelines such as "who yields to whom." Trailheads are excellent locations for signs that explain the type of erosion control methods in use, why certain structures like water bars are needed, and how bicyclists can help reduce resource impacts by modifying their riding technique. Trail closures can be explained and items of interest identified. Often a sign-in station is included as part of the trailhead signing.

Depending on the amount of use and other relevant factors, signs may be desirable at trail intersections and mid-route. If use warrants, minimum signing should consist of reassurance markers and hazard cautions that meet MUTCD shape, color and size standards. Signs may also include identification of the intersection, difficulty ratings for each trail choice, a "you are here" map, trail names and distances, and control signs. Also consider placing caution markers at steep sections and near potentially slick surfaces, such as bridges.

Limit signs to as few words as possible and present information positively. Use international symbols as much as possible, for they help overcome language barriers and present a simple, clear message (Photo 5). Many managers have found that using wording such as "Not Recommended" rather than "No" in sign wording produces a more cooperative atmosphere and better compliance.

In some instances, signing can be reduced by providing bicyclists with a comprehensive guide map. A good example is "Mountain Biking in the Jackson Hole Area," produced by Bikecentennial in partnership with the Bridger-Teton National Forest.

Heavy Use Areas

Trails with heavy mountain bike use can sometimes develop a more curving, rolling, sweeping character. Although the visual impact may be of concern to some managers and users, the changes do not necessarily increase resource impacts. (6) Managers with heavy mountain bike use, such as wildland/urban interface areas, suggest modifying or constructing trails with longer sight distances, increased widths, climbing turns rather than switchback turns, and modified water bars and grade dips. Tread widths of 48 to 50 inches are recommended to allow users to pass more safely and minimize user conflicts. Managers have noted fewer resource impacts, hazards, and user conflicts, and less frequent maintenance necessary when these measures are applied to heavily used trails.(7)

Photo 5. Use of symbols and precise wording makes this an effective sign.

Supplemental Information for Mountain Bike Trail Guidelines

USDA Forest Service Mountain Bike Trail Guidelines (FSH 2309.18 TMH 2.31c) were published in 1985 (see chart, page 6) and have been used by managers to plan or adapt trails for mountain bike use. They appear to be working fairly well, although many managers and bicyclists disagree with the guidelines for maximum pitch and turning radius. Recently, additional information has been gathered by the Missoula Technology and Development Center from users and managers throughout the Forest Service, and it should be included in the planning process.

Trail Difficulty

Establishing trail difficulty ratings is essential to good mountain bike trails. The Guideline's trail difficulty rating system has three classes: Easiest, More Difficult, and Most Difficult. The Guidelines list a number of elements that must be considered when determining mountain bike trail difficulty ratings. Difficulty is determined by considering the relative value of each element and the way it combines with other elements.

Managers must consider both technical and physical difficulty. Technical difficulty involves variations in trail surface (rocky, sandy, boulders, log-strewn), trail alignment, trail width and clearance (low-hanging branches), and the number, length and grade of downhills. Managers should

USDA Forest Service Mountain Bike Trail Guidelines.

	Easiest	More Difficult	Most Difficult[1]
Grade			
Max. Pitch	10%	30%	+30%
Max. Sustained Pitch	5%	10%	15%
Length	100'	300'	500'
Turning Radius	6'	3'	2'
Length of Trip			
Day	10-20 mi.	20-40 mi.	40-50 mi.
One-half Day	5-10 mi.	15-20 mi.	20-25 mi.
Clearing[2]			
Width	48"+	36-48"+	36"
Height	8'	8'	Max. 8'
Tread[3]			
Width	24"+	12-24"+	12"
Surface	Relatively Smooth	Sections of Relatively Rough Surface	Varied-Some PortageRequired

[1] Upper limit of grade and pitch length depends on soil type, amount of rock, vegetation type, and other conditions affecting stability of the trail surface.

[2] Curve alignment to avoid cutting large trees.

[3] Increase tread width 6" on switchbacks or where side slopes exceed 60%.

consider whether riders must steer around rocks, maneuver through tight turns, ride over obstacles and negotiate long or steep downhill sections.

Physical difficulty is concerned with the total distance of the trail and the number, length and grade of uphill sections. Managers should consider the strength and endurance required of the rider.

Using the Guidelines, each trail is rated based on the most difficult section(s). For instance, a loop that begins on a trail section rated Easiest and feeds into a More Difficult section must be rated as More Difficult. Steep climbs, numerous obstacles, and stream crossings may qualify even a short route for a Most Difficult rating. At the same time, a trail that has a smooth surface and very few hills may also be classified as Most Difficult if it is more than 40 miles long.

Photo 6. Numerous or deep stream crossings can increase a trail's difficulty rating.

Because determining trail difficulty is a subjective process, some users may disagree with trail ratings. Quite often mountain bikers who are inexperienced on trails find the Easiest trails to be very difficult, while advanced riders may complain that trails marked Most Difficult should have been marked More Difficult. Trail difficulty designations are intended to provide a general guideline for all users, not to dictate what users are capable of riding. Determining the trail's difficulty varies depending on the evaluator's skill level, experience, and personal biases. Managers can reduce subjectivity by involving mountain biking

enthusiasts of all skill levels in the decision-making process.

Trail difficulty should be clearly posted at appropriate trailheads or provided in trail guides similar to the one developed by the Fishlake National Forest in Utah. "Mountain Bicycling Trails on the Fishlake National Forest" provides maps, reference graphs, and detailed narrative descriptions. The graphs quickly and clearly provide the rider with information about the physical difficulty and total distance of each route, while the narratives detail changes in terrain, features along the route, surface variations, the location of potential hazards and difficult terrain, and more. A well-thought-out guide such as this gives mountain bicyclists the information they need to determine a trail's difficulty as it relates to their skill level.

Information collected from users and managers throughout the Forest Service has been incorporated into the discussion of each of the elements in the Guidelines.

Grade

The steeper the grade and the longer the grade is sustained, the more difficult the trail rating should be. When determining a trail's difficulty level consider the stamina (sustained grade) and strength (maximum pitch) required of the rider in relation to the grade of the trail. Maximum pitch is the highest percent of grade on the trail. Maximum sustained grade is the highest percent of grade on the trail that is sustained for a defined, significant distance.

The Forest Service guidelines recommend a 30 percent maximum pitch on More Difficult and over a 30 percent maximum pitch on Most Difficult trails. Many managers and bicyclists feel that this is too steep. They suggest that on most surfaces a 25 percent pitch is beyond the riding capabilities of the majority of bicyclists. Extended trail stretches of 1/2-mile or more exceeding 15 percent grade should be avoided. Mountain bikers can climb amazingly steep and rugged grades, but very few soil types on grades over 15 percent can endure the use without serious resource impacts occurring (Photo 7). Occasional grades as steep as 25 percent or more are acceptable if they are not over 100 feet in length and the resource can withstand recreational use on such a grade. Steep grades in the trail should not parallel the fall line, but should traverse across the slope. Managers must determine if their trails can support these steep grades.

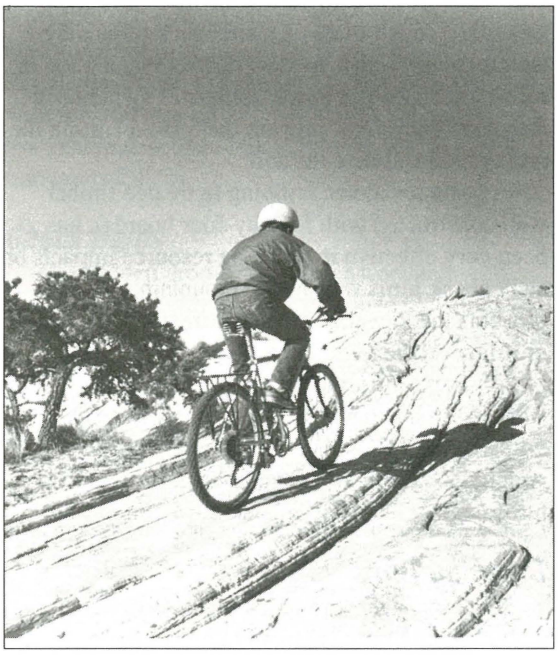


Photo 7. This sandstone surface can withstand trail grades of 15 percent and greater.

Turning Radius

The turning radius on a switchback or climbing turn is the distance from the center of the arc of the turn to the trail. The tighter the turning radius is, the more difficult the trail rating should be. Consider the technical skill required of the rider in relation to the turning radii of switchback and climbing turns along the trail.

The Forest Service guidelines suggest a 6-foot turning radius on Easiest trails, a 3-foot turning radius on More Difficult trails and a 2-foot turning radius on Most Difficult trails. Some managers believe these turns are too tight for mountain bikers traveling downhill, and recommend a 7-foot turning radius for Easiest, 5-foot for More Difficult, and 3-foot for Most Difficult.

Length of Trip

The longer the trail the more difficult its rating should be. When determining a trail's difficulty level, consider the stamina and strength required of the rider in relation to the length of the trail.

Clearing

Clearing is the width and height that the trail is cleared of brush, trees, and other obstacles. The narrower the trail the more difficult its rating should be. Narrow trail clearance challenges the rider's technical skills, particularly balance, braking, and maneuvering. When determining a trail's difficulty level, consider these skills in relation to the clearing width and height of the trail.

Tread

The tread is the portion of the trail on which bicyclists actually travel. A number of things

should be considered in determining the difficulty rating related to tread. The narrowness of the trail tread and whether it is consistent or varied should be considered. The amount of roots, rocks, and other obstacles in the trail challenge the technical ability of the rider. The type of soil (gravel, sand, clay, etc.) and the relative amount of traction it provides is an important consideration. The more obstacles in the trail, the less traction, the narrower the tread, and the greater the variation in surface, the more difficult the trail rating should be. Managers should consider how the width and surface conditions of the tread challenge the technical abilities of the rider.

Alignment

Alignment reflects changes in the vertical and horizontal planes of the trail. The more turns and changes in grade that a trail has, the more difficult the trail rating should be. Consider how the trail alignment relates to the technical skills of braking, balancing, and maneuvering required of the rider.

Exposure

Exposure relates to the number of hazards encountered along the trail, particularly the proximity to steep slopes or cliffs. Often difficulty related to exposure is a mental consideration as well as a physical one. While the trail may be wide and smooth, the idea of riding near a cliff or steep slope may make the trail difficult for some users to ride. In general, the greater the exposure, the more difficult many users will perceive the trail to be.

Construction and Maintenance Techniques

Trail Construction

Environmental damage and user conflicts can be kept to a minimum through careful planning. In addition, there are construction techniques that can further help managers provide safe, enjoyable trail systems. Basic agency construction and maintenance standards can be supplemented with the following construction and maintenance techniques for mountain bicycle trails.

Full Bench Trail Construction

When and where practical, select full bench trail construction rather than 3/4 or 1/2 (balanced section) bench tread. Mountain bikers tend to ride on the outer edge of the tread to keep their inside pedal from scraping the back slope. In areas where cut and fill technique (3/4 or 1/2 bench) is used, the fill dirt may not support the bicycle and rider, and the trail may erode. Disposal of soil from full bench construction must be considered when designing a trail using that construction method.

Outsloping

Sloping the trail to the outer side on low grades will allow water to run off. Bicyclists may tend to veer to the outside of the trail where outsloping has been constructed, but no significant safety problems have been noted. In general, most managers feel that outsloping is an effective method for removing surface water from mountain-bike trails.

Switchback Turns

Resource impacts are often evident on mountain bike trails with switchback turns. On tight switchback turns, bicyclists may skid and/or swing wide in order to negotiate the turn. As they swing wide, the action of the wheels can cause the outer corner of the turn to begin eroding. If the outside of the turn is upslope, an arched erosion site called "eyebrow erosion" may develop. Leaving vegetation close to the edge of the trail or placing rocks and logs along the turn's outer edge may discourage bicyclists from swinging wide as they ride through the turn.

If bicyclists lock their brakes to negotiate downhill turns, their rear wheel sweeps around the corner. This can cause "sheeting erosion," which removes soil and rocks from the trail surface. Leaving a rough tread on switchback turns may encourage bicyclists to slow down. Placing log or rock barriers on the inside corners of switchbacks may slow bicyclists, prevent them from cutting the corner, and stabilize the soil.

In some locations, cribbing (a treated timber wall constructed with four-by-four boards), has been very effective in reducing resource impacts on switchback turns with heavy mountain-bike use. It prevents the bicyclists from cutting the switchback or riding on the outer edge. (6,8)

A volunteer trail building organization that works with managers on the Angeles National Forest uses "J.P.L. Water bars" and "turn in" structures. These are being utilized on switchback turns to slow bicyclists and stabilize the turn. (9)

Climbing Turns

Some managers are replacing switchback turns with climbing turns on mountain bike trails

because of the skidding associated with switchbacks. The climbing turn has a more gradual curve with a wider turning radius, which allows riders to go through the turn with minimal skidding or braking. The wider turning radius accommodates the tendency for the bicyclist to swing wide as they ride through the turn. As a result, climbing turns tend to have less eyebrow and sheeting erosion problems than switchback turns.

However, some managers warn that bicyclists are able to travel faster through climbing turns, and this may increase user conflicts. Managers must decide whether the switchback or climbing turn will work best given the type and volume of users and the potential resource impacts. If switchback turns are converted to climbing turns, the radius must be widened and tread profile rebuilt with a 20 percent inslope. Water control structures may need to be established above and below the turn to remove water. (10)

Water Control Structures

Collector Ditches

These ditches can be hazardous to mountain bicyclists who, if they take their eyes off of the trail for a moment, might ride into them. If ditches cannot be moved away from the edge of the trail or feathered in from the trail, it is best to forgo ditches where other satisfactory drainage techniques can be used.

Grade Dips (Drainage Dips)

Because grade dips do not have rocks, logs or a dramatic drop-off in their structure, mountain bicyclists can ride into these structures safely and easily. Grade dips should be incorporated in the initial construction of the trail. They blend in well with the trail, are effective in removing water, are low maintenance, and bicyclists do not typically ride around them.

Check Dams

The sudden drop-off/step-up associated with check dams may throw or destabilize bicyclists as they attempt to ride into them. Most bicyclists tend to ride around check dams, rather than dismount and walk over them. When bicyclists ride around check dams, alternate routes are created that channel water around the structure and back onto the trail. This increases resource impacts and the check dam becomes ineffective. Place rock or log barriers on the sides of the check dam to discourage cyclists from riding around them. Be sure that water can move through or around these barriers without adding to the erosion potential. To encourage cooperation from cyclists, post information that explains how riding around check dams can increase erosion.

Water Bars

The small drop-off and slippery rocks and logs associated with water bars can destabilize bicyclists when they ride over these structures. For this reason, many bicyclists ride around water bars. Where possible in new trail construction, grade dips, rather than water bars, should be constructed. In reconstruction, consider installing rubber water deflectors or modified water bar structures rather than conventional water bars. If water bars must be used, place rock or log barriers beside the structure to help keep users on the trail.

Modified Water Bars

Managers on the Los Padres National Forest in California made adjustments to the traditional water bar structure to create a small dip at the upper end of the water bar (Illustration 3a). These dips are similar to water bars but do not have rocks or logs in their structure. The upslope end of the ditch is slightly humped above or even with the level of the trail, and mountain bikers ride past the structure on the hump. The rest of the ditch is the same as an earthen water bar, except that it has a more steeply angled slope into the discharge area. These dips work best where trails are outsloped and climates are dry. Because such structures are not stabilized by rocks or logs, they require frequent maintenance.(11)

Managers on the Routt National Forest in Colorado are using double sunken log structures (Illustration 3b) to replace traditional water bars on their mountain bike trails. These structures are similar to open-top drains used on roads. Two logs are buried at a 45- to 90-degree angle to the trail (depending on local conditions), with 6 to 8 inches between them. The uphill log is level with the trail surface and the downhill log is a bit higher than the surface. Water flows over the first log and into the drain between the two logs. The drain then carries the water off the trail. Both logs are buried so bicycle wheels do not slip on the structure.(12) Treated dimension lumber can be used for this structure.

Some managers have successfully used "rolling dip" water bars (Illustration 3c), which have logs buried beneath fill material. The fill over the log is rounded on the top and sloped down gradually in both directions. The water is drained away before it reaches the log. It is critical that the log is completely covered and that the mound and the drain uphill of the mound are smoothed in a

Illustration 3. Modified water bars.

3a. Small Dip

3b. Double Sunken Logs

3c. Rolling Dip

gradual rolling dip profile, to allow bicyclists to ride over a small hump without slipping on logs or rocks. (13)

Managers on the Angeles National Forest are using trail hardening blocks (also known as "Tread Support Blocks" or "Turf Stone"— not to be confused with cinder blocks) in place of rock or log water bars. They've found that water bars with hardening blocks require far less maintenance and provide more traction than rock-and-log water bars. (14)

Rubber Water Deflectors

Rubber water deflectors consist of two 2-inch by 10-inch boards nailed together with a piece of 1/2-inch by 13-inch rubber sandwiched between them. This structure is then installed in a manner similar to a water bar. Because the rubber strip is flexible, it is easier for cyclists to ride over the structure, and because there are no rocks or logs associated with this deflector, they are less likely to slip as they cross over it.

Some managers have reported problems with the rubber laying over as it fills with sediment. When the rubber fills with sediment and bends downhill, it is difficult for cyclists to ride uphill against it. To reduce this problem, limit the height of the rubber to between 2-1/2 and 3 inches – tall enough to move water off the trail but not to obstruct bicycle traffic. The reduced height also decreases the tendency of the rubber to stay bent.

If an adequate outlet and grade are provided, these deflectors are self-cleaning. Some managers have increased grades into the deflectors or have constructed 12-inch wide ditches against the upslope side of the structures to reduce the accumulation of sediments against the rubber strip. The deflector should be installed at a 30 to 45 degree angle to reduce skidding. (If set at too great an angle, such as 60 degrees, bicycle tires may be deflected off the trail.) (See Appendix B.)

Trail Surfacing

Rough Natural Surfacing

A clean, smooth trail allows bicyclists to increase their speed. This may intensify resource impacts and user conflicts. Where appropriate, leave a rougher surface with rocks and roots and other natural or human-made barriers in place to help slow riders' speed.

Aggregate Surfacing

Aggregate or gravel surfaces can be used to protect wet areas from erosion and slow the bicyclist's speed. Allow adequate visibility in advance of such changes in the trail surface so that cyclists can see and prepare for the change. On some aggregate trail surfaces designed for people with mobility disabilities, bicyclists can create ruts and make it difficult for people who use wheelchairs to negotiate the trail. This problem can sometimes be resolved by mixing the aggregate with local soils and providing adequate compaction. Check with soil specialists to ensure that the most appropriate aggregate material is used at each site. (15)

Raised Tread With Crowning

For very wet areas or for trails along level terrain, the tread surface can be crowned by building it slightly above the ground level to minimize resource impacts and discourage multiple routes from being created. Bicyclists might ride along the graded slope, which can cause erosion problems, but posting explanations of the reason for the crowned tread and why cyclists should ride in the center of the trail may help reduce the problem. (16)

Trail Hardening Blocks

Managers are using these blocks, also known as "Turf Stone" and "Tread Support Blocks," to armor and protect trail surfaces from erosion. They have been used effectively on steep sections of trail, in stream banks and beds, and in water bar structures where mountain bike use is heavy.

Tread Structures

Puncheon and Corduroy

Puncheon and corduroy planks should be spaced no wider than one inch apart, for wider spacing can allow bicycle wheels to catch in the gaps. Wet or frost-covered planks also can be hazardous, so managers may want to post warning signs at trailheads or at crossings. Puncheon should never be aligned parallel to the trail. This can cause the bicycle tire to be trapped.

Bridges and Boardwalks

Some cyclists are intimidated by riding on narrow structures, such as bridges and boardwalks. Because moisture and frost on flat surfaces can reduce traction, bicyclists should avoid riding on bridges and boardwalks with turns or on arched bridges when the surface is wet or frost-covered.(7) Wheel guards (logs placed along the edges of these structures) act as bumpers to prevent bicyclists from slipping off the edge of a boardwalk or bridge, and will enhance their confidence. So will handrails which, if constructed on bridges or boardwalks, should have a minimum width of 4 feet between handrails. This width assures adequate clearance for the handlebars. Brush should be kept clear of handrails, so that cyclists can clearly see them.

Maintenance and Control Measures

Trail Edge Barriers

Bicyclists tend to ride on the outside edge of the trail to keep their pedal from scraping against the backslope. Rock or log barriers can be placed along the outside edge of the trail to keep the edge from eroding. However, there must be adequate tread width for bicyclists to pass without scraping their pedals on the backslope. A 6-foot spacing between barriers should allow proper drainage.

Stream Crossings

If stepping stones are placed in creeks or streams for hikers, place them slightly upstream or downstream in order to leave the main thoroughfare clear for bicyclists to ride through the crossing.

Trail Clearing

Excessive clearing allows bicyclists to travel faster and leave the tread when cornering. Where it is appropriate, narrow the clearing width by leaving brush close to the trail's edge. However, overhanging vegetation or projecting tree limbs should always be removed if they create a hazard.

Trail Closure Considerations

Safety, user conflicts, and resource impacts should be considered when determining if a trail should be reconstructed, relocated, or closed. If possible, other measures should be explored before closing trails. Consider leaving the trail open if it has no significant safety problems or potential for resource impacts, but simply appears undesirable for mountain bike use. Trails with extended steep sections, numerous stream crossings, rough surfaces, or long sections where the bicycle must be carried can be signed as not recommended

Photo 8. This sign has been effective in limiting bicycle use on certain trails.

(Photo 8) for bicycle use. There are bicyclists who are looking for challenge, and these trails may appeal to them. Indicating that these trails are not recommended for bicycle use allows the rider to determine if the trail meets their needs.

Some trails may require temporary or seasonal restrictions. For example, some erosion-prone trails or sections of trails may need to be closed during the wettest or driest periods of the year (Photo 9, page 12). Likewise, travel on trails that pass through important wildlife habitat might need to be controlled during nesting, calving, and mating seasons. Explain the reasons for closures at trailheads to help reduce confusion and frustration on the part of users.

Communication

Careful planning, design, and communication can help managers provide all trail users with safe, enjoyable recreation experiences. Cooperation and

Photo 9. Managers should consider temporary closures for trails that flood during heavy rains.

information-sharing are effective tools for reducing conflict, safety problems, and resource impacts on mountain bike trails. The Bicycle Federation of America guide, *Mountain Bikes on Public Lands: A Manager's Guide to the State of the Practice*, does an excellent job of presenting ways to involve, inform, and educate users. This guide supplements that information.

Opposition to mountain bike use often occurs in wildland/urban interface areas or trails with established horse or hiker use. Resistance to mountain bike use appears to be primarily related to a few factors: bicyclists may travel faster than other users; people are often startled by the sudden approach of a quiet bicyclist; new visual impacts have been created; and mountain bikers are the newest group of users competing for access to a limited and increasingly crowded public trail system. Although most cyclists don't ride at excessive speeds, some do and this can cause user conflicts and resource impacts.

Mountain bike organizations are working hard to minimize resource impacts and reduce the number of user conflicts. Many of these organizations are anxious to work with managers and other user groups. All users should be informed of the need to work together to identify and solve environmental and safety concerns. Effective communication is the best way to prevent user dissatisfaction and conflict.

Encourage users to form clubs or participate in other trail groups, get involved in policy making, organize volunteer patrols, and volunteer to maintain and construct trails. Trail managers and bicycle groups can form partnerships to create new and improve existing mountain biking opportunities on public lands (Photo 10). Some managers are sponsoring "Trail Days" where different kinds of users come together to demonstrate their sports. These gatherings can easily be combined with a "work day" where volunteers join to inspect, maintain, and reconstruct trails. This is an excellent opportunity for managers to explain the use of erosion control measures, and for users to voice their concerns. For example, managers can discuss the need to close a muddy trail to mountain bike and horse travel, and users can identify why and where an alternate route should be opened. These gatherings allow both users and managers an opportunity to express their ideas and clarify their concerns.

Designing trails that can be used by mountain bicyclists in summer and nordic skiers in winter is another effective way to encourage user groups to work together. Both user groups enjoy trails with rolling terrain and sweeping turns.

Such trails should be designed to provide for the needs of both users. For instance, ideally the canopy along these trails should be open enough to prevent both the interception of falling snow and the falling of melting snow onto the trail. (Aspect is important on ski trails because north-facing

Photo 10. This bicycle campground near Jackson, Wyoming, is the result of a partnership between the Forest Service and Bikecentennial.

slopes have a better snow-holding capacity.) Transition periods between seasons can be sensitive, and temporary closures may be necessary. If the trails are to be suitable for skiers, bicyclists cannot be permitted to use them once snow begins to accumulate. Also, the potential for resource impacts is great when the snow begins to melt in the spring. If existing ski trails are adapted for bicycle use, the trail should be checked in its wettest period so that erosion-prone areas can be identified. Debris must be cleared and quite often a tread must be built.

Some managers worry that mountain bikers will not use wide ski trails, but wide trails with dips and turns are attractive to many mountain bikers. The Birkebeiner Ski Trail in Hayward, Wisconsin, ranges from 40 to 50 feet wide (Photo 11). Well known for its excellent nordic skiing opportunities, it also offers premier mountain biking experiences and is used for organized mountain bike events. The Rendezvous Ski Trails in West Yellowstone, Montana, are also popular with mountain bikers and are another excellent example of successful shared-use trails.

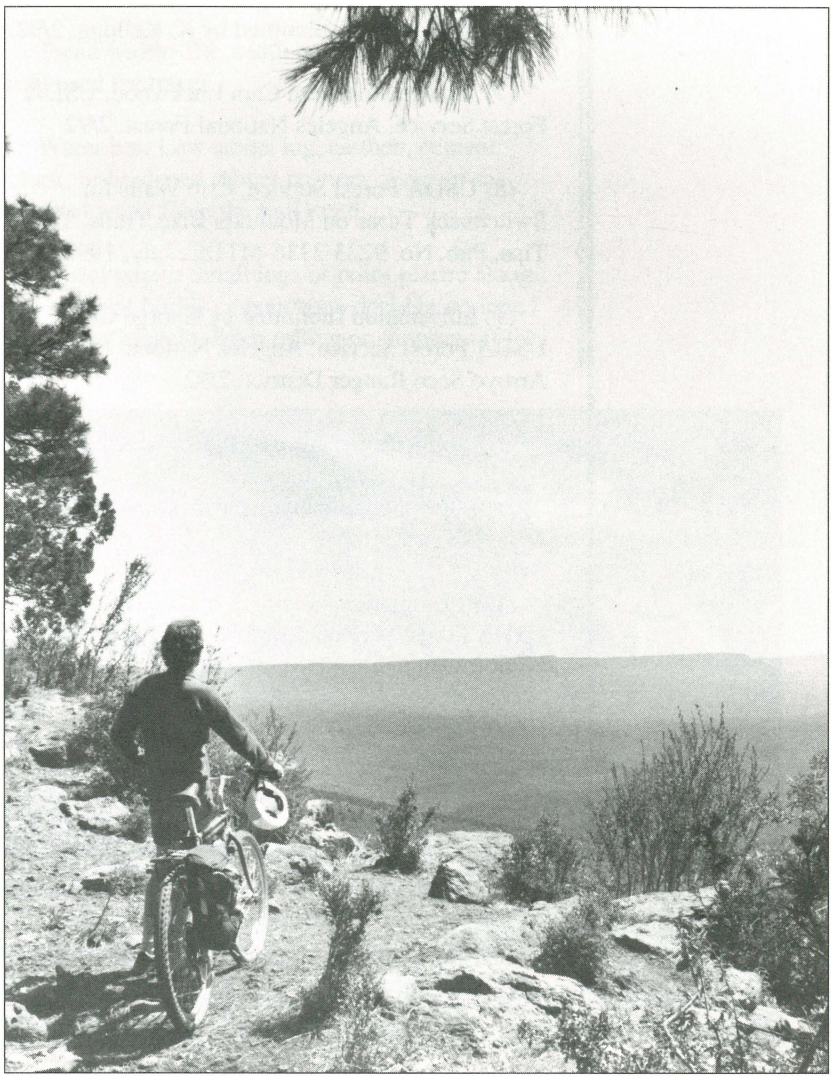
Rules and regulations must be applied without discrimination and should be rigorously enforced. Inconsistent enforcement (patrolling or restricting only one user group) can lead to confusion and mistrust. Consider implementing volunteer patrols that use peer groups to educate and inform. (Consult with local law enforcement officials concerning civil liability issues and the limited legal authority of volunteer patrols.)

Opportunities for partnerships and cooperation with adjacent private land owners should be explored. A properly placed trail can extend trail diversity, disperse users, minimize resource impacts and reduce conflicts on trails. (17) User groups can work with private land owners and discuss access concerns. If access has not been established, carefully design trails away from private lands. Encourage users to respect the gate closure needs of all land owners.

Trail guides are another effective tool for informing and educating users. Managers on the Lolo National Forest in Montana, in cooperation with Bikecentennial, have developed a guide for mountain bikers. It provides standard information about trip length and difficulty, thorough route descriptions, and information on trail etiquette, safety, and how to protect the environment. Trail guides may also include information on cultural resource features, viewpoints, fishing and camping opportunities, changes in trail surface and width, sustained grades, river crossings, habitat types, other roads and trails, gate closures, and local services. Producing a trail guide is also an excellent way to develop partnerships with local bicycle businesses and organizations.

With time, patience, commitment, and cooperation on the part of all users and managers, mountain bikers can be successfully integrated into the trail family. This publication was developed to assist in that process. ■

Photo 11. The Chequamegon Fat Tire Festival Race is held each year on the Birkenbeiner Ski Trail.



Footnotes

(1) Information gathered from a conversation with Kerry Kellogg, USDA Forest Service, Los Padres National Forest, Santa Barbara Ranger District. 8/91

(2) Information gathered from conversation with Andy Kulla, USDA Forest Service, Lolo National Forest. 9/91

(3) Information gathered from a conversation with Mike Dolfay, USDA Forest Service, Wenatchee National Forest. 8/91

(4) "Pathways for People- Trail Design to Minimize Environmental Damage and Enhance User Enjoyment" by Wendy Hultsman and John Hultsman, Purdue University Publication of Forestry and Natural Resources.

(5) Information submitted by A. Kulla. 8/91.

(6) Information submitted by K. Kellogg. 2/92.

(7) Information from Cam Lockwood, USDA Forest Service, Angeles National Forest. 2/92

(8) USDA Forest Service, Crib Walls for Switchback Turns on Mountain Bike Trails, Tech Tips, Pub. No. 9223-2336-MTDC, July, 1992.

(9) Information submitted by George Geer, USDA Forest Service, Angeles National Forest, Arroyo Seco Ranger District. 2/92

(10) Information from C. Lockwood. 2/92

(11) Information gathered from conversation with K. Kellogg. 8/91.

(12) Information submitted by Don Hoffheins, USDA Forest Service, Routt National Forest, Middle Park Ranger District. 1/92

(13) Information submitted by Thomas Schmidt, USDA Forest Service, Ochoco National Forest. 3/91

(14) Information gathered from conversation with C. Lockwood. 2/92

(15) Information gathered from conversation with M. Dolfay. 8/91

(16) Information gathered from conversation with Phil Gezon, Bureau of Land Management, Butte, Montana. 8/91

(17) Information submitted by P.Gezon. 2/92

Glossary

Alignment: The layout of a trail in horizontal and vertical planes (bends, curves, uphill and downhill). The more the alignment varies, the more challenging the trail usually is for mountain bicyclists.

Aspect: The compass direction that a trail faces. Aspect affects a site's amount of solar radiation and its year-round moisture content (including length of snow season) and type and amount of vegetation.

Backslope: The angle of the backwall of a trail which is excavated into a hillside.

Clearing: The corridor, both vertical and horizontal, from which vegetation is cleared.

Climbing turn: A turn of less than 180 degrees located on an up- or downhill section of trail.

Clinometer: A device used to measure percent of grade or slope.

Collector ditch: A drainage structure for intercepting water flowing toward a trail. The water is usually channeled from the ditch through a culvert underneath the trail.

Crowning: A trail construction technique used to drain water off the trail bed. The highest point of the trail is in the center and the sides are sloped out and down at less than a 2 percent angle.

Double-track trail: A trail that allows for two users to ride side by side or pass without one user having to yield the trail. Double-track trails are often resource roads that are closed to motorized vehicles.

Drainage dip: An erosion-control device in which the grade of a trail is reversed for 10 to 20 feet. The dip is accompanied by an outslope which diverts water off the trail tread.

Exposure: The relative hazard encountered when one takes into consideration obstacles, alignment, grade, clearing, tread width, tread surface, sideslope, isolation, and proximity to steep slopes or cliffs.

Full Bench: A trail made entirely by excavating into a steep sideslope; that is, no fill is used to support the trail.

Grade: The slope the trail maintains in its direction of travel, measured in percentage (feet change in elevation for every 100 horizontal feet).

Inslope: A downward slope toward the inside of the trail; causes water to run along the inside of the trail.

Interest and avoidance areas: Features that a trail should either intersect or avoid.

Loop concept: Designing trail systems so that the routes form loops, giving bicyclists the option of not riding the same section of trail more than once on a trip.

Maximum pitch: The highest percent of grade on a trail.

Maximum sustained pitch: The highest percent of grade on a trail that is sustained for a defined distance.

Modified water bar: An erosion control structure that has been modified to reduce the slippage and drop-offs that are associated with traditional water bar structures.

Obstacles: Physical objects that are large enough to impede or slow travel. Logs, roots, rocks, and ledges are common obstacles.

Outslope: A downward slope toward the outside of the trail; causes water to run off the trail tread.

Pitch: An increase in the prevailing grade of a trail, used during construction to avoid an obstacle, to catch up with the intended grade, or to meet a control point.

Rubber water deflector (also called cross-belted drain tabs or belt water bars): A type of water bar that consists of a piece of hardened rubber bolted between two pieces of lumber. The rubber used is often industrial-strength conveyor belt.

Shared-use trail: A trail that accommodates more than one user group at a time (horse, hiker, bicyclist, etc.)

Single-track trail: A trail wide enough for only one user to ride; requires one user to yield trail to another when passing.

Switchback: A sharp turn, usually of about 180 degrees, used to decrease the grade of a trail traveling up or down a steep slope. Typically used on sideslopes of 30 percent and greater.

Trail bed: The trail tread, along with the soil underneath and around it.

Trailhead: The beginning of a trail system; a staging area.

Tread (or tread surface): The portion of a trail on which users actually travel. A tread is more difficult to ride if its surface is loose, rough, slippery, etc.

Tread width: The width of the portion of the trail used for travel.

Water bar: Low stone, log, earthen, cement block, or hardened rubber barriers designed to channel water from the trail tread.

Wheel guard: Small logs or poles placed along the edges of bridge or puncheon decking designed to prevent bicycles from rolling or slipping off the structure.

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Appendix A

MOUNTAIN-BIKE TRAIL DATA SHEET

Ride Name_____

Date_____Researcher_____

Others on Ride_____

_____

_____

Ride Distance_____Ride Time_____

Beginning Elevation_____Ending Elevation_____

Highest Elevation _____Cumulative Gain_____

Steepest grade_____Length_____

Surfaces Ridden_____

_____

Weather_____

Base Map_____

USGS Map(s)_____

_____

Access to trailhead (from town or campground)

_____

_____

_____

Nearest food/water source:_____

_____

Relative difficulty _____

_____

Comments (observations; special attractions, considerations, hazards...)

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Narrative_____

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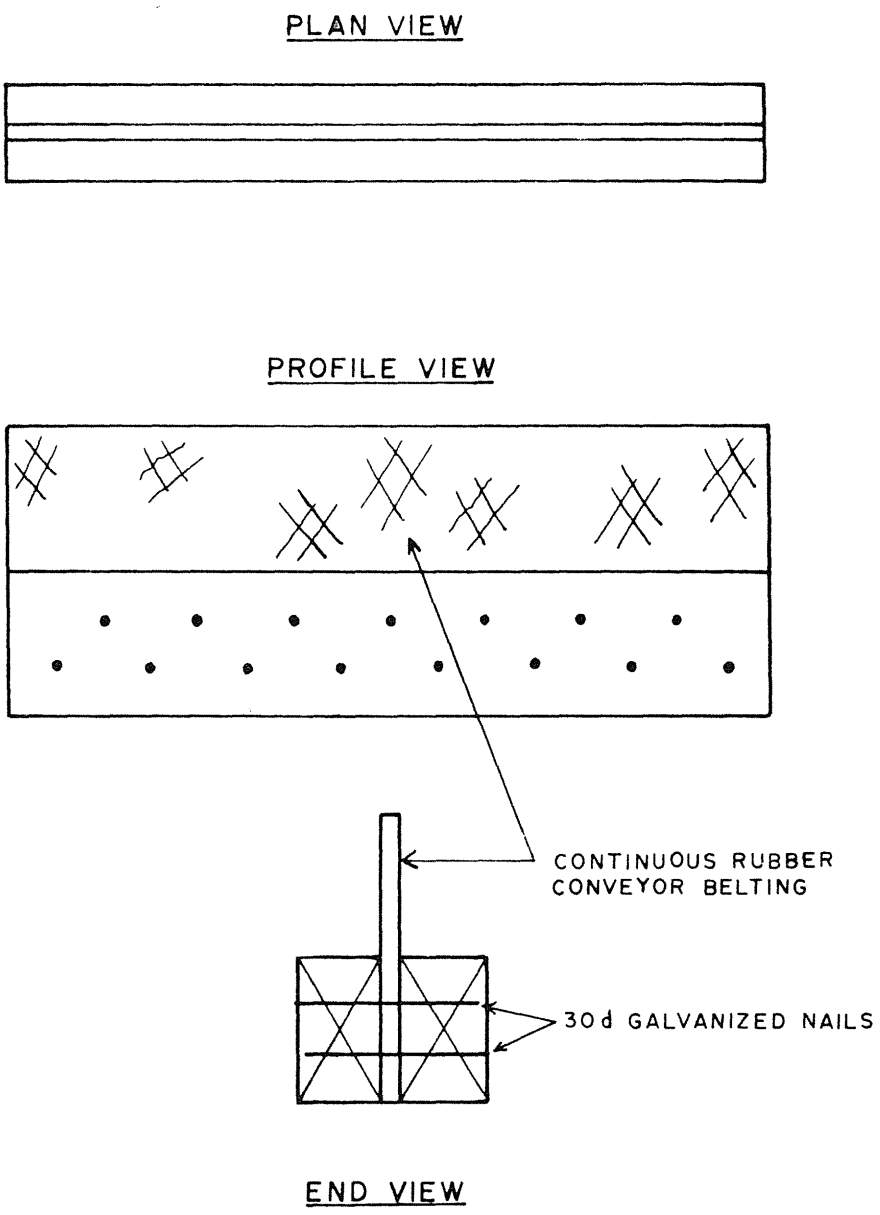
REVERSE SIDE: Sketch map (if necessary)

Appendix B

USDA - FOREST SERVICE - GM, UNC & GUNN N.F.

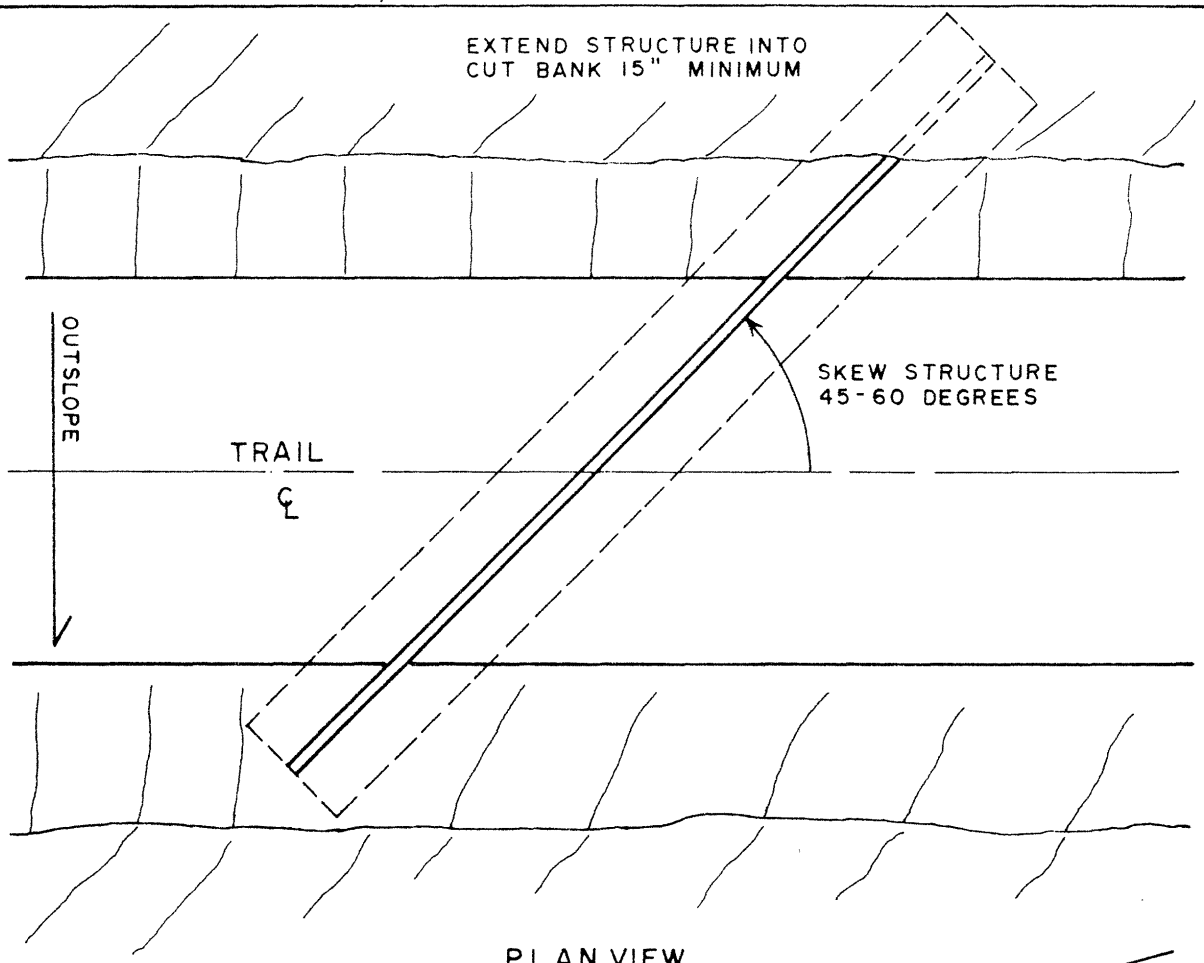


USE 30d GALVANIZED NAILS
4" NAILING PATTERN, IN 2 ROWS, STAGGERED

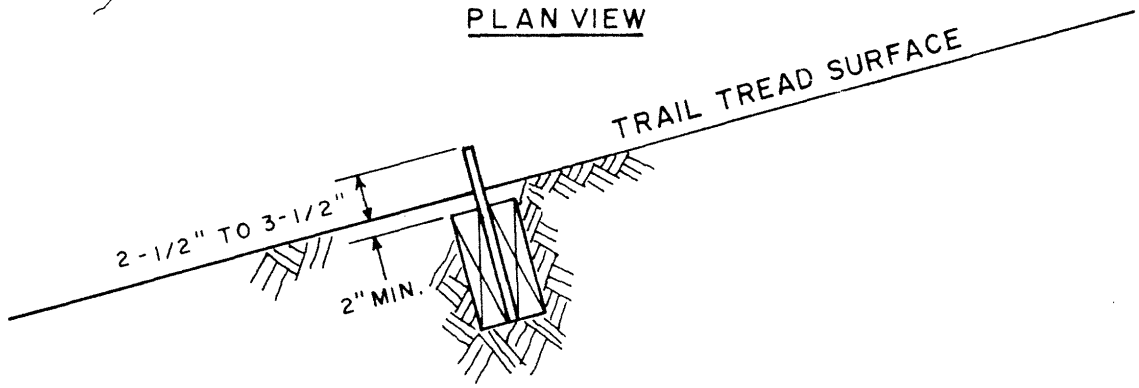
CONTINUOUS RUBBER BELTING WATERBAR

GM-7700-78 (4/90)

USDA - FOREST SERVICE - GM, UNC & GUNN N.F.



PLAN VIEW



PROFILE VIEW

CONTINUOUS RUBBER BELTING WATERBAR

GM-7700-78A (4/90)

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